



Software Diversification for WebAssembly

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Abstract

WebAssembly, now the fourth officially recognized web language, enables web browsers to port native applications for the Web. Importantly, WebAssembly has evolved into an essential element for backend scenarios such as cloud computing and edge computing. Therefore, WebAssembly finds use in a plethora of applications, including but not limited to, web browsers, blockchain, and cloud computing. Despite the emphasis on security since its design and specification, WebAssembly remains susceptible to various forms of attacks, including memory corruption and side-channels. Furthermore, WebAssembly has been manipulated to disseminate malware, particularly in cases of browser cryptojacking. Interestingly, the predictability of the WebAssembly ecosystem, encompassing its consumers and hosted programs, is remarkably high. Such predictability can amplify the effects of vulnerabilities within these ecosystems. For instance, a defect in a web browser, triggered by a faulty WebAssembly program, could potentially impact millions of users.

This thesis aims to bolster the security within the WebAssembly ecosystem through the introduction of Software Diversification methods and tools. Software Diversification is a strategy designed to augment the costs of exploiting vulnerabilities by making software unpredictable. The unpredictability within ecosystems can be diminished by automatically generating various program variants. These variants strengthen observable properties that are typically used to launch attacks, and in many instances, can completely eliminate such vulnerabilities. Nonetheless, the application of Software Diversification in the context of WebAssembly has yet to be explored.

This work introduces three groundbreaking tools: CROW, MEWE, and WASM-MUTATE. Each tool has been specifically designed to tackle a unique facet of Software Diversification. Furthermore, these tools complement each other. We present empirical evidence demonstrating the potential application of Software Diversification to WebAssembly programs in two distinct ways: Offensive and Defensive Software Diversification. Our research into Offensive Software Diversification in WebAssembly unveils potential paths for enhancing the detection of WebAssembly malware. On the contrary, our experiments in Defensive Software Diversification show that WebAssembly programs can be fortified against side-channel attacks, specifically the Spectre attack.

Keywords: WebAssembly, Software Diversification, Side-Channels, Moving Target Defense

Sammanfattning

LIST OF PAPERS

1. ***WebAssembly Diversification for Malware Evasion***
Javier Cabrera-Arteaga, Tim Toady, Martin Monperrus, Benoit Baudry
Computers & Security, Volume 131, 2023, 17 pages
<https://www.sciencedirect.com/science/article/pii/S0167404823002067>
2. ***Wasm-mutate: Fast and Effective Binary Diversification for WebAssembly***
Javier Cabrera-Arteaga, Nicholas Fitzgerald, Martin Monperrus, Benoit Baudry
Submitted to Computers & Security, under revision, 17 pages
<https://arxiv.org/pdf/2309.07638.pdf>
3. ***Multi-Variant Execution at the Edge***
Javier Cabrera-Arteaga, Pierre Laperdrix, Martin Monperrus, Benoit Baudry
Moving Target Defense (MTD 2022), 12 pages
<https://dl.acm.org/doi/abs/10.1145/3560828.3564007>
4. ***CROW: Code Diversification for WebAssembly***
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Measurements, Attacks, and Defenses for the Web (MADWeb 2021), 12 pages
<https://doi.org/10.14722/madweb.2021.23004>
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Javier Cabrera-Arteaga, Shrinish Donde, Jian Gu, Orestis Floros, Lucas Satabin, Benoit Baudry, Martin Monperrus
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<https://doi.org/10.1145/3397537.3397567>
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Javier Cabrera-Arteaga, Martin Monperrus, Benoit Baudry
11th ACM SIGPLAN International Workshop on Virtual Machines and Intermediate Languages (SPLASH 2019), 10 pages
<https://doi.org/10.1145/3358504.3361228>

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Contents

List of Papers	iii
Acknowledgement	iv
Contents	1
I Thesis	4
1 Introduction	5
1.1 Predictability in WebAssembly ecosystems	8
1.2 Problems statements	9
1.3 Software Diversification	9
1.4 Summary of research papers	10
2 Background and state of the art	13
2.1 WebAssembly	13
2.1.1 From source code to WebAssembly	14
2.1.2 WebAssembly's binary format	17
2.1.3 WebAssembly's runtime	18
2.1.4 WebAssembly's control-flow	20
2.1.5 Security and Reliability for WebAssembly	21
2.1.6 Open challenges	22
2.2 Software diversification	23
2.2.1 Automatic generation of software variants	24
2.2.2 Equivalence Checking	26
2.2.3 Variants deployment	27
2.2.4 Measuring Software Diversification	28
2.2.5 Offensive or Defensive assessment of diversification	29
2.3 Open challenges for Software Diversification	30

3	Automatic Software Diversification for WebAssembly	32
3.1	CROW: Code Randomization of WebAssembly	33
3.1.1	Enumerative synthesis	34
3.1.2	Constant inferring	35
3.1.3	Exemplifying CROW	36
3.2	MEWE: Multi-variant Execution for WebAssembly	38
3.2.1	Multivariant call graph	39
3.2.2	Exemplifying a Multivariant binary	39
3.3	WASM-MUTATE: Fast and Effective Binary Diversification for WebAssembly	42
3.3.1	WebAssembly Rewriting Rules	43
3.3.2	E-Graphs traversals	44
3.3.3	Exemplifying WASM-MUTATE	45
3.4	Comparing CROW, MEWE, and WASM-MUTATE	47
3.4.1	Security applications	50
4	Assessing Software Diversification for WebAssembly	52
4.1	Offensive Diversification: Malware evasion	52
4.1.1	Cryptojacking defense evasion	53
4.1.2	Methodology	54
4.1.3	Results	56
4.2	Defensive Diversification: Speculative Side-channel protection	60
4.2.1	Threat model: speculative side-channel attacks	61
4.2.2	Methodology	61
4.2.3	Results	63
5	Conclusions and Future Work	69
5.1	Summary of technical contributions	69
5.2	Summary of empirical findings.	70
5.3	Future Work	71
5.3.1	Improving WebAssembly malware detection via canonicalization	71
5.3.2	Code pattern feedback-guided Diversification	72
	References	74
II	Included papers	88
	WebAssembly Diversification for Malware Evasion	90
	Wasm-mutate: Fast and Effective Binary Diversification for WebAssembly	91

<i>CONTENTS</i>	3
CROW: Code Diversification for WebAssembly	92
Multi-Variant Execution at the Edge	93
Superoptimization of WebAssembly Bytecode	94
Scalable Comparison of JavaScript V8 Bytecode Traces	95

Part I

Thesis